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OFFICE OF THE SECRETARY

Re: Comments regarding NPRM PR Docket No. 92-257

Gentlemen:

Enclosed are comments regarding Notice of Proposed Rule Making 92-257. I respectively request that the Commission consider these comments during evaluation of this proposal.

George W. Henry, Jr.
President

enc: Comments Regarding NPRM Docket No. 92-257
Appendix: "Chapter 3 CLOVER-II Waveform & Protocol"

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List ABCDE

Before the
Federal Communications Commission
Washington, D.C. 20554

Comments Regarding:

In the Matter of	)	NPRM Docket 92-257
Amendments of the Commission's	)	RM-7956
Rules Concerning Maritime	)	RM-8031
Communications	)	

To: The Commission:

COMMENTS CONCERNING
NOTICE OF PROPOSED RULE MAKING
PR DOCKET NO. 92-257

HAL COMMUNICATIONS CORP.
1201 W. Kenyon Road
P.O. Box 365
Urbana, IL 61801

George W. Henry, Jr.
President

May 27, 1993

HAL Communications Corp., an Illinois corporation, requests that these comments concerning NPRM Docket No. 92-257 be considered. We submit the following information pertinent to the discussion of technology (Item 13) and Narrow-Band Direct Printing telegraph (Item 19).

HAL Communications Corp. is a manufacturer of radio data communications equipment. HAL has provided data terminals and modems for use with HF (high-frequency) radio equipment in support of ship-to-shore communications since 1972. Our modems support Narrow-Band Direct-Printing (NBDP) radio telegraph communications as defined by CCIR-476, CCIR-625, and CFR47, Part 80.219.

As noted in Item 13 of the NPRM (Technology), the number of users of the very limited number of HF NBDP data channels is expanding at a rapid rate. The HF spectrum is presently very crowded and offers little hope for expansion by simply increasing the number of frequency channels available, or, conversely, increasing the emission bandwidth allowed in each channel. Rather, new technology must be exploited to make more efficient use of the existing resources.

HAL has recently developed new HF radio modem technology that is directly applicable to NBDP maritime applications. Called "CLOVER", the new modulation waveform occupies the same bandwidth as a CCIR-625 data signal (500 Hz), but provides considerably more robust error correction and greatly increased data throughput (from 4 to 10 times faster than CCIR-625). CLOVER is specifically designed to combat distortion and errors created by ionospheric propagation of HF radio signals. HAL submits that use of the CLOVER modulation waveform will greatly increase the data throughput over the limited number of maritime NBDP increases the net data throughput and therefore the efficiency of each radio data transmission.

CLOVER modems constantly monitor received signal conditions (signal-to-noise ratio, and phase dispersion). The modulation format of the transmitter is then adaptively set by the receiving ARQ station to match current ionospheric propagation conditions. When propagation permits, data throughput is as high as 70 bytes-per-second. Under very poor conditions, data is still passed at 7.7 bytes-second, slightly higher that the rate at which *all* data is passed using CCIR-625 protocol (6.67 characters-per-second), under all ionospheric conditions.

CLOVER modems transfer full 8-bit bytes of data and may be used to send computer data and text files, reproducing the full character and symbol set of the data source. By comparison, CCIR-476 and CCIR-625 NBDP systems pass only a limited set of characters and symbols - one case of letters and limited punctuation symbols.

The CLOVER waveform and protocol are described in detail in the enclosed Appendix, an extract from the HAL Communications Corp. manual for the PCI-4000 CLOVER modem.

HAL Communications Corp. therefore requests that, in regard to Item 19 of NPRM 92-257, the commission revise the technical requirements for use of NBDP in the maritime services as follows:

(1) The *occupied bandwidth* of all NBDP HF radio emissions as defined by CFR47, Part 2.202(a) shall not exceed 500 Hz.

(2) That the CCIR-625 emission continue to be the default HF radio waveform and protocol, but not limit operation of suitably equipped ship and shore stations to only CCIR-625.

(3) Remove all specific requirements for modulation format and baud rate (presently FSK modulation @ 100 baud maximum). These specifications are only applicable to the older and simpler FSK waveform used for CCIR-625 emissions. Modern modulation waveforms such as CLOVER are much more efficient, do not use non-phase-coherent FSK modulation, and may send more than one data bit per change in on-the-air modulation state.

Respectively submitted,

HAL Communications Corp.

George W. Henry, Jr.
President

APPENDIX
to

Comments by HAL Communications Corp. Regarding
FCC NPRM Docket No. 92-257

CLOVER-II WAVEFORM & PROTOCOL

The following material is excerpted from the HAL Communications Corp. equipment manual PCI-4000 CLOVER-II DATA MODEM REFERENCE MANUAL, Chapter 3, pages 3-1 through 3-21; copyright HAL Communications Corp., Urbana, IL; November 16, 1993 printing.

CHAPTER 3
CLOVER-II WAVEFORM & PROTOCOL

The PCI-4000 hardware is designed for use as a HF radio modulator/demodulator (modem). This chapter provides details of the PCI-4000 CLOVER-II waveform.

3.1 CLOVER Background

"CLOVER" is the name of a series or class of modem modulation techniques ("waveforms") specifically designed for use over high frequency (HF) radio systems. The "CLOVER-II" waveform used in the PCI-4000 was developed by Ray Petit and HAL Communications. CLOVER waveforms are characterized by the following general properties:

a. Very low base data rate.
b. Time-sequence of amplitude-shaped pulses.
c. Very narrow frequency spectra.
d. Differential modulation between pulses.
e. Multi-level modulation

3.2 CLOVER-II Waveform

3.2.1 Time/Frequency Domain

The CLOVER-II waveform in the PCI-4000 modem uses four tone pulses which are spaced in frequency by 125 Hz. Default parameters of PC-CLOVER set the following center and tone pulse frequencies:

Fc =	2250.0 Hz	F(center)
F1 =	2062.5 Hz	F(tone pulse #1)
F2 =	2187.5 Hz	F(tone pulse #2)
F3 =	2312.5 Hz	F(tone pulse #3)
F4 =	2437.5 Hz	F(tone pulse #4)

The four tone pulses are sent in time sequence with 8 milliseconds (ms) between the center of each pulse (8 ms between pulse 1 and 2, 8 ms between pulse 2 and 3, etc.). A complete tone pulse sequence is repeated every 32 ms; i.e., 32 ms elapse between the 1st and 2nd occurrence of tone pulse #1. The four tone pulses are then combined to produce the composite tone pulse sequence diagramed in Figure 3.1. Figure 3.2 shows a three dimensional amplitude, time, and frequency representation of the CLOVER-II modulating signal. Figure 3.3 shows the resulting CLOVER-II frequency spectra.

Please note that while Figures 3.1 and 3.2 have been simplified and idealized to clarify this discussion, Figure 3.3 shows the actual measured spectra of CLOVER-II modulation at the PCI-4000 modulator output terminals.

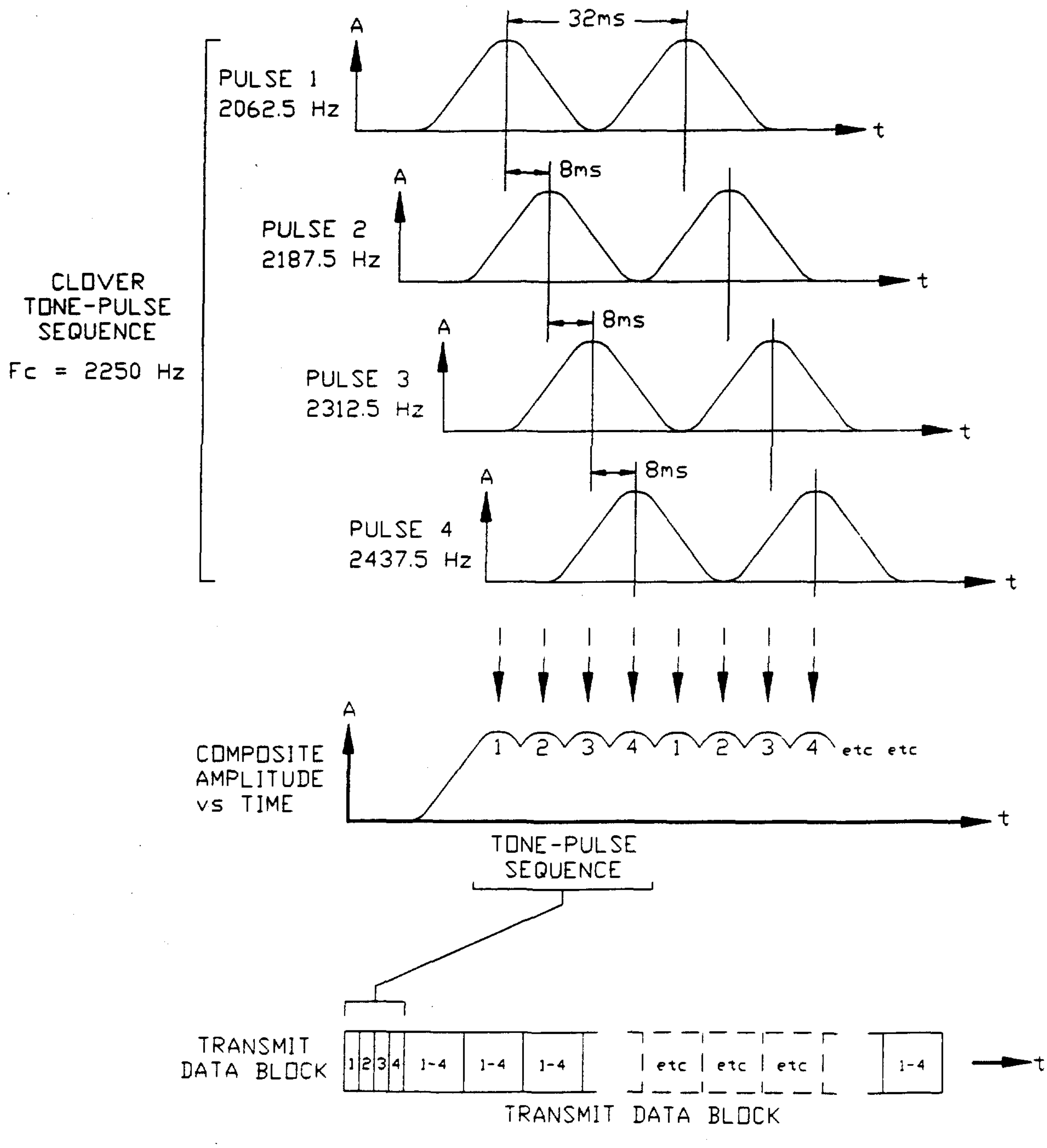
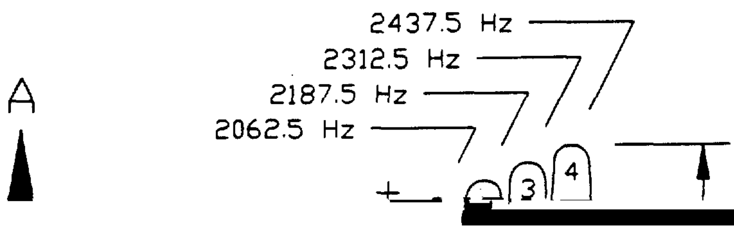


Figure 3.1 CLOVER-II Tone Pulse Sequence


2437.5 Hz
2312.5 Hz
2187.5 Hz
2062.5 Hz
A
3
4

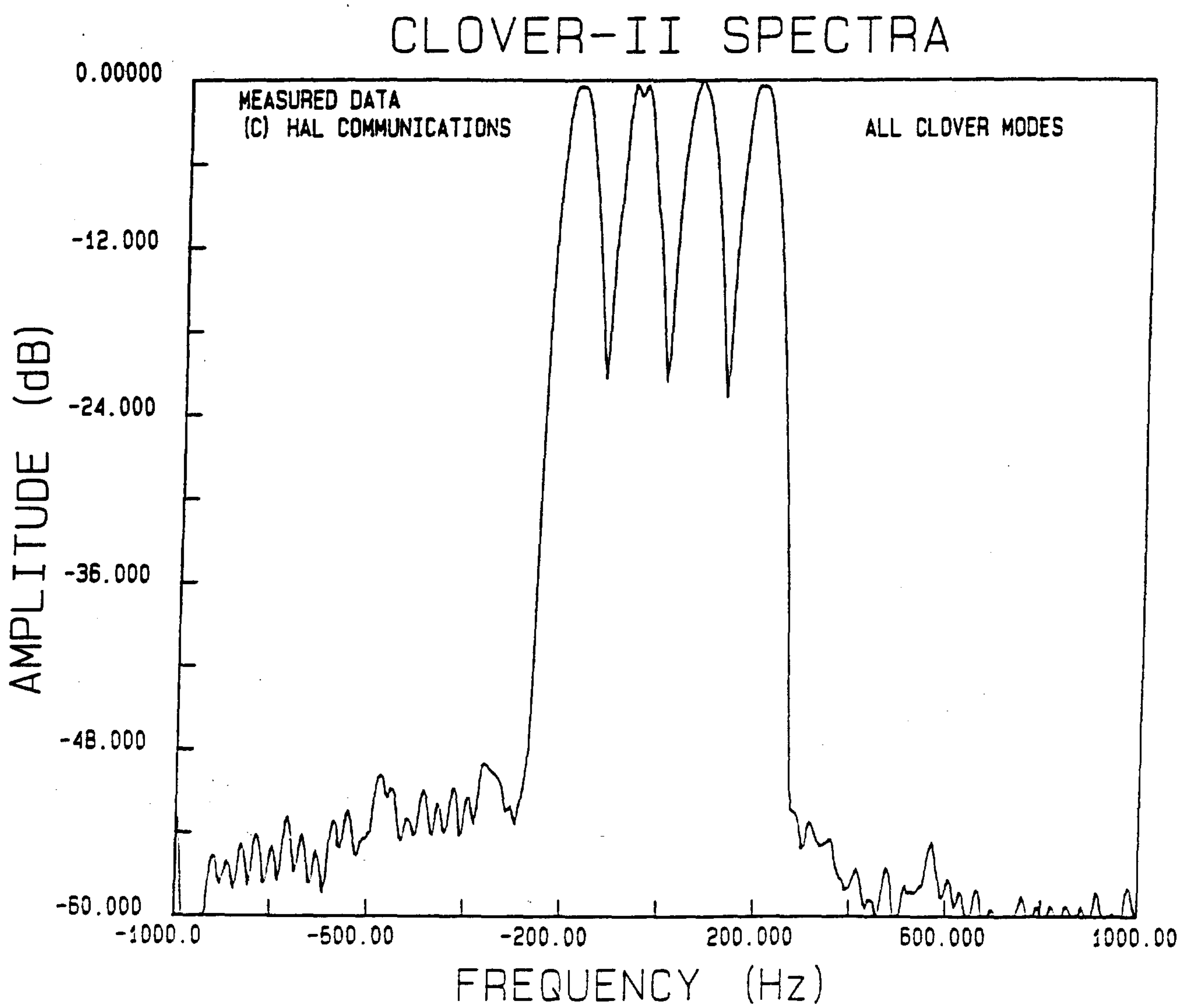


Figure 3.3 CLOVER-II Frequency Spectra

The spectral efficiency of a CLOVER-II signal is quite evident in Figure 3.3. This spectra is obtained by using amplitude shaping of each of the four tone pulses. A Dolph-Chebychev function with -60 dB side-lobe level is used as the shaping function.

> *NOTE: CLOVER-II is a J2 emission that is applied to the audio input of an SSB HF transmitter. "FSK" modes provided in some HF transmitters cannot be used with CLOVER-II modulation.*

Key parameters of the CLOVER-II emission are:

Occupied Bandwidth	=	500 Hz @ -50 dB below peak level
Crest Factor	=	Peak/Average
	$\leq$	2:1 (voltage)
	$\leq$	6 dB (power)
CCIR Emission	=	500H J2 DEN or 500H J2 BEN

3.2.2 Data Modulation

Data is impressed or modulated upon the CLOVER-II signal by varying the phase and/or amplitude of the tone pulses. Further, all data modulation is differential on the same tone pulse; data is represented by the phase (or amplitude) *difference* from one pulse to the next. For example, when binary phase modulation is used, a data change from "0" to "1" may be represented by a change in the phase of tone pulse #1 by 180 degrees between the 1st and 2nd occurrence of that pulse. Note that the phase is changed between occurrences of a tone pulse (while the pulse amplitude is zero) and *not* when the tone pulse is turned ON. Therefore, the phase of each tone pulse is constant for the entire time that the pulse is "ON". This is true for all modulation formats of CLOVER-II.

The CLOVER-II spectra is the <u>same</u> for all modulation forms.

CLOVER-II uses four tone pulses. The phase and/or amplitude of each tone pulse is modulated and demodulated as a separate narrow-bandwidth data channel. As noted above, all modulation of a tone pulse is differential - between occurrences of a given tone pulse. Since the time spacing between tone pulse frames is fixed at 32 ms:

The base modulation rate of a CLOVER signal is <u>always</u> 31.25 symbols/sec.

This low symbol rate makes CLOVER-II demodulation extremely resistant to pulse width/delay distortion that is caused by multiple path HF propagation. For example, time dispersion caused by HF "multi-path" distortion may often cause a time uncertainty of 1 to 5 ms in the received signal. Traditional FSK data demodulation systems are very susceptible to this distortion whenever the dispersion approaches 1/4 to 1/2 of the basic pulse width. For this reason, use of FSK is generally restricted to minimum pulse widths of 7 to 13 ms, corresponding to maximum FSK data rates of 75 to 150 baud. Higher FSK data rates may sometimes be used on HF, but only when multi-path distortion is low (usually when the operating radio frequency is close to the Maximum Usable Frequency, or "MUF"). Because of its low symbol rate (31.25 bps):

CLOVER-II is extremely tolerant of HF "multi-path" distortion.

CLOVER-II uses multiple tone channels to increase the effective data throughput rate. The previous example used binary phase shift modulation (BPSM) on tone pulse #1. Actually, the same modulation format is applied to all four tone pulses of CLOVER. Thus, 4 data bits are sent by differential binary phase modulation for each 32 ms tone pulse frame. Even though the base modulation rate is 31.25 bits-per-second (bps), the actual throughput using BPSM on all four tone pulses is four times that, or, 125 bps. This is one way in which CLOVER-II sends data at a relatively high throughput rate but maintains a very low base rate.

CLOVER-II uses multiple tones to increase data throughput.

Note the above usage of "Phase Shift Modulation" (PSM) rather than "Phase Shift Keying" (PSK). Since "PSK" is traditionally used to describe the modulation of a constant carrier which results in a wide signal bandwidth, the phrase "Phase Shift Modulation" (PSM) is used to describe CLOVER which uses differential modulation when tone pulses have zero amplitude and does not produce a wide frequency spectra.

In much the same manner that using four tones increases the data throughput, CLOVER also uses multi-level differential phase modulation of each tone pulse. For example, if each pulse is modulated using QPSM (Quad Phase Shift Modulation), the differential phase of each pulse may be changed in 90 degree increments, 2 bits of data modulated on each tone pulse, and 8 bits of data sent in each 32 ms four tone-pulse frame. This increases the net data throughput by a factor of 8 from the base rate (to 250 bps). Similarly, 8-ary PSM (8-level, 8PSM) provides throughput of 375 bps and 16-ary PSM (16-level, 16PSM) provides throughput of 500 bps. In all cases, the base symbol rate for any one CLOVER-II tone pulse remains at 31.25 bps and the total spectra is as shown in Figure 3.3.

Extending this concept even further, CLOVER includes two amplitude modulation modes: 2-level and 4-level Amplitude Shift Modulation (2ASM, 4ASM). 4-level ASM is used with 16PSM to produce the fastest modulation with a net throughput of 750 bps. Also, 2-level ASM may be used with 8PSM modulation to produce 500 bps throughput.

CLOVER-II uses multi-level and multi-format differential modulation to increase data throughput.

A logical question at this point might be:

"If multi-tone and multi-level modulation produces high throughput, why bother with the slower data modes?

The answer is, of course, that complex modulation modes also require high detector precision and very stable signals. For example, consider that 16PSM uses phase changes of 22.5 degrees to represent the state of 4 data bits per tone pulse. To accurately detect this change, the phase "jitter" or dispersion caused by propagation must also be less than $\pm$ 11.25 degrees. Further, the receiver's detector must be capable of resolving phase changes as small as $\pm$11.25 degrees which means that the internal phase reference for detection must be very phase stable. In short:

Stable ionosphere conditions are required to use the "faster" modes.

Recognizing that HF propagation conditions are often less than optimum and may deteriorate rapidly from "ideal" conditions, CLOVER-II includes several very robust modulation modes as well as the "fast" modes. These robust modes take advantage of the four tone pulses of CLOVER-II for narrow-bandwidth diversity modulation and demodulation. For example, 2DPSM is dual diversity binary phase shift modulation in which the same data is repeated on alternate CLOVER tone pulses (#1 and #3 and #2 and #4). Upon reception, both copies of each data bit are examined and combined to minimize errors. Of course, the net throughput is also reduced from 125 bps (BPSM) to 62.5 bps (2DPSM), but with a corresponding improvement in detection accuracy. Similarly, 4DPSM mode sends the same data bits on each of the four tone pulses, providing four-channel diversity, gaining even more detection accuracy, but at an even slower throughput rate (31.25 bps).

Since some ionospheric paths may be extremely phase dispersive, CLOVER includes two Frequency Shift Modulation (FSM) modes, FSM and 2DFSM. In FSM mode, tones #1 and #3 form one frequency-shift pair to send one bit of data and tones #2 and #4 another frequency-shift pair, sending a second bit of data. The throughput is therefore 2 times, the base symbol rate (62.5 bps). In a manner similar to that used in PSM modes, 2DFSM provides two-channel diversity in which the same data is sent in paired channels #1/#3 and #2/#4 with a throughput of 31.25 bps.

CLOVER-II supports a total of 10 different modulation formats: 6 using Phase Shift Modulation (PSM), 2 using Amplitude Shift Modulation (ASM, with PSM), and 2 using Frequency Shift Modulation (FSM).

> *Multiple modulation modes allow CLOVER to operate over a wide range of ionosphere conditions.*

The ten CLOVER-II modulation modes are shown in Table 3.1. Adaptive ARQ mode control is discussed in section 3.3.3.3.

TABLE 3.1
CLOVER-II MODULATION MODES

NAME	DESCRIPTION	IN-BLOCK DATA RATE
16P4A	16 Phase, 4-Amplitude Modulation	750 bps
16PSM	16-level Phase Shift Modulation	500 bps
8P2A	8 Phase, 2-Amplitude Modulation	500 bps
8PSM	8-level Phase Shift Modulation	375 bps
QPSM	4-level Phase Shift Modulation	250 bps
BPSM	Binary Phase Shift Modulation	125 bps
2DPSM	2-Channel Diversity BPSM	62.5 bps
FSM	Frequency Shift Modulation	62.5 bps
4DPSM	4-Channel Diversity BPSM	31.25 bps
2DFSM	2-Channel Diversity FSM	31.25 bps

3.2.3 Error Detection and Correction

HF radio can be a very cost-effective and convenient means to send digital data over very long distances. This is particularly true in locations which are not served by wire lines (telephone) and satellite relays are either not available or very expensive. HF radio equipment can be quickly placed in remote field locations and is often ideal for use in emergencies and locations which lack any other means of communications.

However, HF radio propagation may add severe distortion to data signals, causing errors and loss of data. The task of the HF modem device is to accept ionosphere distortion as it occurs and adjust, correct, or compensate the recovered signal to minimize data errors or loss.

CLOVER-II uses special *forward error correction (FEC)* data encoding which allows the receiving station to correct errors without requiring a repeat transmission. This is a very powerful error correction technique that is not available in other common HF data modes such as AX.25 packet radio or AMTOR ARQ mode.

Reed-Solomon FEC data coding is used in all CLOVER modes. This is a byte and block oriented code. Errors are detected on bytes of data (8-bits) rather than on the individual bits themselves. This block-oriented code is ideally suited for HF use in which errors due to fades or interference are often "bursty" (short lived) but cause total destruction of a number of sequential data bits. CLOVER-II data is sent in fixed-length blocks of 17 bytes, 51 bytes, 85 bytes, or 255 bytes.

Error correction at the receiver is determined by "check" bytes which are inserted in each block by the transmitter. The receiver uses these check bytes to reconstruct data which has been damaged during transmission. The *capacity* of the error corrector to fix errors is limited and set by how many check bytes are sent per block. Obviously, check bytes are also "overhead" on the signal (non productive data bytes) and their addition effectively *reduces the efficiency and therefore the "throughput rate" at which user data is passed* between transmitter and receiver.

CLOVER-II has four "coder efficiencies" options: 60%, 75%, 90%, and 100% ("efficiency" being the approximate ratio of real data bytes to total bytes sent). "60% efficiency" corrects the most errors but has the lowest net data throughput. "100% efficiency" turns the Reed-Solomon encoder OFF and has the highest throughput but fixes *no* errors. There *is therefore a trade-off between raw data throughput vs the number of errors which can be* corrected without resorting to retransmission of the entire data block.

Note that while the "EFFECTIVE DATA RATE" numbers listed in Table 3.1 go as high as 750 bps (bits-per-second), inclusion of other desired features in CLOVER add overhead and thus reduce the *net* throughput or *overall efficiency* of a CLOVER transmission. Reed-Solomon error correction encoding makes CLOVER very robust in the face of severe ionospheric distortion but also reduces the efficiency of the transmission. As will be noted in later sections, protocol requirements of FEC and ARQ modes for synchronization and control also add overhead and reduce the net efficiency.

Tables 3.2 and 3.3 detail the relationships between block size, coder efficiency, data bytes per block, and correctable byte errors per block.

TABLE 3.2
DATA BYTES TRANSMITTED PER BLOCK

BLOCK SIZE	Reed-Solomon Encoder Efficiency 60%	75%	90%	100%
17	8	10	12	14
51	28	36	42	48
85	48	60	74	82
255	150	188	226	252

TABLE 3.3
CORRECTABLE BYTE ERRORS PER BLOCK

BLOCK SIZE	Reed-Solomon Encoder Efficiency 60%	75%	90%	100%
17	1	1	0	0
51	9	5	2	0
85	16	10	3	0
255	50	31	12	0

Reed-Solomon data coding is the primary means by which errors are corrected in CLOVER "FEC" mode (also called "broadcast mode"). In ARQ mode, CLOVER-II employs a three-step strategy to combat errors. First, channel parameters are measured and the modulation format is adjusted to minimize errors and maximize data throughput. This is called the "Adaptive ARQ Mode" of CLOVER-II. Second, Reed-Solomon encoding is used to correct a limited number of byte errors per transmitted block. Finally, data blocks in which errors exceeding the capacity of the Reed-Solomon decoder are repeated. Adaptive ARQ mode is discussed in section 3.3.3.2.

3.2.4 CLOVER Waveform Modes

As detailed in Table 3.1, CLOVER-II has a set of ten different modulation formats which may be used to send and receive data. In addition, each of these modulation formats may be sent using four data block lengths (17, 51, 85, or 255 bytes) and four Reed-Solomon coder efficiencies (60%, 75%, 90%, and 100%). There are *160 different waveform modes* which could theoretically be used to send data via CLOVER (10 x 4 x 4). However, the performance characteristics of many of these modes overlap (minimum S/N, data throughput, phase dispersion tolerance, etc). Other system limitations and considerations for optimizing the FEC and ARQ protocols place further limits on the selection of block length and coder efficiency in particular. When these factors are weighed and optimized, the result is that there are 6 to 8 different waveform combinations which may be used in each protocol. The optimum waveform modes for each protocol are discussed in the following sections.

3.2.5 Baud, Data Rate, and Throughput

The terms "Baud", "data rate", "overhead", and "throughput" are all used to describe CLOVER-II emissions. The following conventions are used to describe data "speeds" of CLOVER-II:

The SYMBOL RATE of CLOVER-II is always 31.25 Baud.

This is true for all modulation forms and all error-corrector settings of CLOVER. It is true for either FEC or ARQ modes.

The Data Rate in CLOVER-II varies with the modulation form.

Data rate is a measure of the rate at which data bits may be sent using the various forms of modulation available in CLOVER-II. The data rate is always an integer multiple of the *symbol rate* (31.25) of CLOVER-II. As may be seen in Table 3.1, multi-level modulation provides data rates of 31.25, 62.5, 125, 250, 375, 500, and 750 bps (bits-per-second). As used in this discussion, data rate numbers *do not* include the effects of "overhead".

"Overhead" is used to describe any function or operation in CLOVER-II that diverts transmitted bits or adds time delays which tend to reduce the data flow between transmitter and receiver below that implied by the modulation data rate. The Reed-Solomon error corrector diverts data bits (actually data bytes) for error correction use; block numbering and check sums also require data bytes. These are all necessary overhead parameters that are necessary for proper operation but which also reduce the number of bytes in each block that may be used to send data between stations.

As will be described in following sections, FEC and ARQ modes each add overhead to the CLOVER transmission. FEC and ARQ both require CLOVER Control Blocks (CCB's) for synchronization and link control. ARQ mode adds time delays to switch transmitters and receivers ON and OFF. These are also necessary overhead parameters which further reduce the net rate at which data may be passed.

For the purpose of clarity, CLOVER-II documentation uses *throughput* to describe the over-all rate at which data is passed between transmitter and receiver. Further, throughput using CLOVER-II is described in units of *bytes-per-second (bps)*. Unless otherwise

3.3 CLOVER-II Protocols

CLOVER-II data may be sent using FEC ("broadcast") or ARQ protocols. In addition, each of these protocols have minor variants which are tailored for specific applications. A unique and optimum set of waveform parameters is offered for each protocol.

3.3.1 CLOVER Control Block (CCB)

The CLOVER Control Block (CCB) is the coordinating control signal used in all CLOVER protocols - FEC and ARQ. The CCB contains information which tells the receiving modem details of the data blocks which will follow. The CCB is used to:

a. Send MYCALL
b. Send Waveform parameters of data blocks
c. Synchronize receiver detector
d. Connect request (ARQ mode)
e. Disconnect request (ARQ mode)
f. Repeat request (ARQ mode)
g. Keyboard entry text (ARQ mode when time permits)
h. Exchange channel statistics (ARQ mode, when time permits)
i. Call CQ (ARQ mode)

The CCB is *always* sent using a very robust waveform format. In general, the CCB uses 17 byte blocks with 60% coder efficiency. Also, the CCB usually uses a modulation mode that is one or two levels more robust than that used for the following data frames. Correct reception of the CCB is essential to further reception and decoding of data blocks that follow.

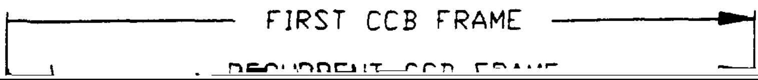
3.3.2 FEC Protocol

CLOVER-II FEC mode allows a sending station to transmit data to one or more receiving stations. This mode is also often called a *broadcast* and sometimes an *unproto* mode. FEC mode is a one-way transmission and does not provide error correction via repeat transmission. However, the Reed-Solomon error correction encoder (section 3.2.3) is used to provide receive error correction of all FEC transmissions.

FEC mode transmission does not use adaptive waveform control. Rather, the sending station must choose a transmitting modulation format in advance and assume that conditions between his station and all other stations are adequate for the chosen mode.

Since FEC transmissions cannot use repeat transmission or adaptive waveform selection, all FEC transmissions are sent using 75% Reed-Solomon error correction efficiency. The block lengths used for each FEC data "speed" are chosen for an optimum balance of throughput and receive synchronization requirements in a changing ionosphere.

The data transmission format used for FEC mode is shown in Figure 3.4.


FIRST CCB FRAME

Note in Figure 3.4 that each group of data blocks is preceded by the transmission of a CLOVER Control Block (CCB). The CCB announces the sending station's call sign and the modulation format of the data blocks which follow. Also note that the CCB and each data block are separated by "gaps" (no-signal periods) and a reference tone pulse frame.

The 32 ms "gaps" between CCB and data blocks are used to dynamically measure the received Signal-To-Noise ratio (S/N) and adjust signal detection in CLOVER to current operating conditions. This allows the CLOVER demodulator to quickly compensate for rapidly varying signal amplitudes when propagation is poor or when receiver AGC is adversely affected by interfering signals. The 32 ms "REF" period at the start of each CCB and data block provides the frequency and phase reference required to decode the balance of the CCB or data block.

The FEC data waveform modes vary for each FEC rate chosen. These modes are chosen to optimize FEC performance (throughput, error correction, and system synchronization) for each rate. The FEC CCB is always sent using 2DPSM modulation, 17 byte block size, and 60% encoder efficiency. Six data throughput choices are available for FEC transmission. Details of FEC modes are shown below in Figure 3.4 and Table 3.4.

TABLE 3.4
FEC MODES

RATE	CCB	BLOCK WAVEFORM	BLKS/ CCB	BLOCK TIME	T-PUT (byps)
58	2DPSM	16P4A/255/75	9	2.720	57.6
39	2DPSM	16PSM/255/75	6	4.080	38.7
30	2DPSM	8PSM/255/75	5	5.440	29.5
20	2DPSM	QPSM/255/75	3	8.160	19.5
10	2DPSM	BPSM/85/75	5	5.440	9.4
5	2DPSM	2DPSM/51/75	4	6.528	4.7

The "Rates" shown in Table 3.4 are approximations of the computed bytes-per-second data throughput rates (last column) for each setting. Throughput calculation is based upon 8-bit bytes and includes time required for "overhead" functions (CCB, reference sequence, gaps). The effect of shorter bit-lengths per character or code compression is not included in these calculations. The BLOCK WAVEFORM is abbreviated in the format [Modulation]/[Block Size]/[Coder Efficiency]. For example:

8PSM/255/75 = 8-ary Phase Shift Modulation
= 255 byte blocks
= 75% Reed-Solomon code efficiency

The "BLOCK TIME" column shows the time required to transmit each block of data. Since CLOVER uses a block protocol, all bytes in a block must be received before any data in the block can be passed to the receiving device - i.e., displayed on the receive terminal. Therefore, the "BLOCK TIME" is an indicator of how frequently the receive screen will be updated with new text.

3.3.3 ARQ Protocol

ARQ is the "work-horse" mode of CLOVER-II. While messages may be *broadcast* using FEC mode (one point to multiple point transmission), only ARQ mode provides fully adaptive and error-corrected communications. ARQ is a two-station point-to-point mode; one station "links" to a second station and data flows between the two stations. The full advantages of adaptive waveform control and error correction via repeat transmission are provided to these two stations.

The CLOVER-II ARQ protocol is actually two-layered. The lower, more basic layer involves exchange of only CLOVER Control Blocks between the two ARQ stations. All link maintenance operations are performed at the CCB level. This structure assures that the ARQ link integrity is always preserved. While a limited amount of data may also be exchanged within the CCB's (called "Chat Mode"), bulk data transfers are made at a high, *data block layer* of the ARQ protocol. The data block layer uses longer blocks and high-rate modulation waveforms to expedite data transfer.

3.3.3.1 CCB Protocol Layer

CLOVER Control Blocks (CCB's) are used to coordinate the two ARQ stations. As is the case for FEC mode, CCB's in ARQ mode are always sent using a *more robust waveform* than that used for data transmission. ARQ CCB's always have a block length of 17 bytes and a coder efficiency of 60%. CCB's perform the link control functions listed in section 3.3.1.

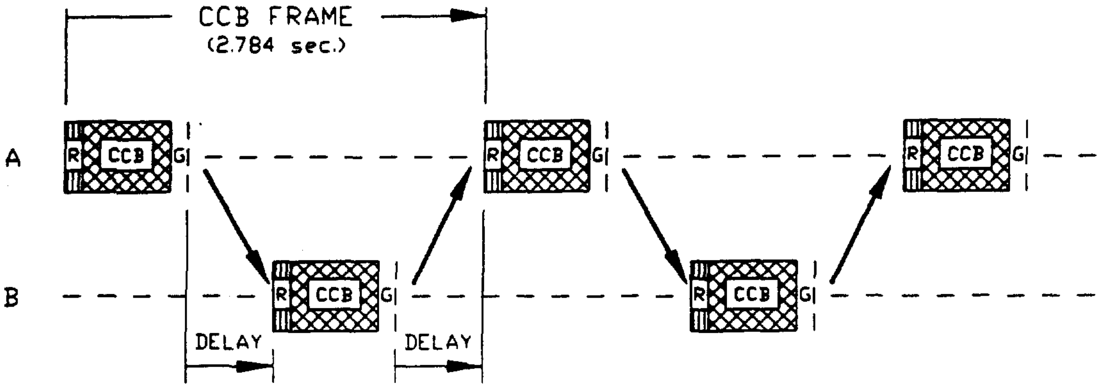
In ARQ mode, CLOVER Control Blocks (CCB's) *always* use the following waveform format:

Modulation	=	BPSM =	Binary Phase Shift Modulation
Block Size	=	17 bytes	
Efficiency	=	60%	

This is a very robust, but slow waveform format. This CCB structure is used for modulation modes from BPSM (125 bps) up through 16P4A (750 bps).

The timing structure of the CCB-layer of the ARQ protocol is shown in Figure 3.5. The "CCB Frame" includes time delays to compensate for propagation delays, transmitter/receiver delays, and modem processing delays.

CLOVER-II BASIC ARQ CCB FRAME



R = Reference Sequence = 0.032 sec.
CCB = CLOVER Control Block
= BPSM/17/60 = 1.088 sec.
G = No-Signal Gap = 0.032 sec.

DELAYS:
t(prop) = Propagation = 0.096 sec. (max)
t(filter) = Filter Delay = 0.032 sec.
t(coder) = R-S Coder = 0.080 sec.
t(PTT) = PTT Delay = 0.032 sec.

CCB FRAME TIMING:

PARAMETER	TIME	TPS FRAMES
REF (A)	0.032	1
CCB (A)	1.088	34
GAP (A)	0.032	1
t(A-B prop)	0.096	3
t(B-fil)	0.032	1
t(B-coder)	0.080	2.5
t(B-PTT)	0.032	1
REF (B)	0.032	1
CCB (B)	1.088	34
GAP (B)	0.032	1
t(B-A prop)	0.096	3
t(A-fil)	0.032	1
t(A-coder)	0.080	2.5
t(A-PTT)	0.032	1
	2.784 sec.	87.0 TPS Frames

NOTE: 'TPS' = Tone Pulse Sequence (32 ms)

Figure 3.5 ARQ Mode - CCB Layer Timing

3.3.3.2 ARQ Data Block Layer

Data is communicated between two ARQ stations by adding a series of data blocks to the CCB protocol. This mode is illustrated in Figure 3.6. Although the CCB's waveform parameters remain fixed, the waveform of the data blocks is adaptively adjusted to match current propagation conditions. The throughput rate during data block transmission is generally much higher than that used for the CCB's.

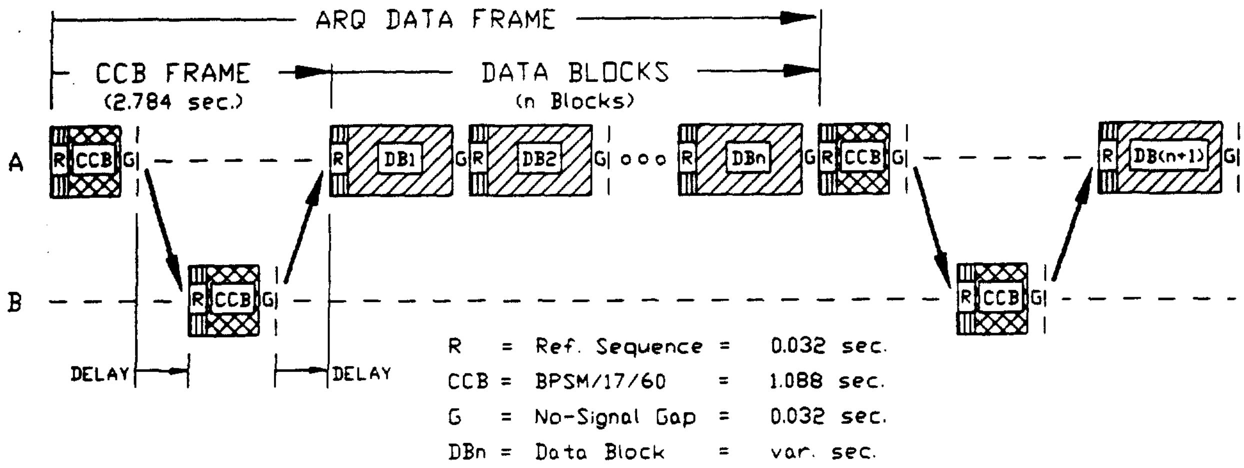
As in the case of FEC, a varying number of data blocks are sent in each ARQ/CCB time frame. The number of data blocks and other timing parameters are adjusted so that the total time for each ARQ frame is exactly 19.488 seconds, regardless of modulation waveform combination used. 255 byte long data blocks are used in all ARQ modes. The Reed-Solomon coder efficiency is set to 60%, 75%, or 90% depending upon the *ARQ Bias* selected (Robust, Normal, and Fast bias, respectively). ARQ bias will be discussed in section 3.3.3.4. ARQ mode parameters are shown in Figure 3.6.

3.3.3.3 Adaptive ARQ (AUTO-ARQ)

The CLOVER-II AUTO-ARQ mode provides a three-fold strategy to attack the problems of HF data signal distortion.

1. Reed-Solomon forward error correction on all data transmitted. Using NORMAL

CLOVER-II MULTI-BLOCK ARQ DATA FRAME



ROBUST

ROBUST BIAS (60%) RATE	MOD	BLOCK	BYTES/ FRAME	MAX ERRORS	BLOCK TIME	BLKS/ FRAME	ARQ FRAME TIME	THRU-PUT BYTES/SEC
46	16P4A	255	900	300	2.720 sec	6	19.488 sec	46.2
30	16PSM	255	600	200	4.080 sec	4	19.488 sec	30.8
30	8P2A	255	600	200	4.080 sec	4	19.488 sec	30.8
23	8PSM	255	450	150	5.440 sec	3	19.488 sec	23.0
15	QPSM	255	300	100	8.160 sec	2	19.488 sec	15.4
8	BPSM	255	150	50	16.320 sec	1	19.488 sec	7.7

RMAL

NORMAL BIAS (75%) RATE	MOD	BLOCK	BYTES/ FRAME	MAX ERRORS	BLOCK TIME	BLKS/ FRAME	ARQ FRAME TIME	THRU-PUT BYTES/SEC
58	16P4A	255	1128	186	2.720 sec	6	19.488 sec	57.9
39	16PSM	255	752	124	4.080 sec	4	19.488 sec	38.6
39	8P2A	255	752	124	4.080 sec	4	19.488 sec	38.6
28	8PSM	255	564	93	5.440 sec	3	19.488 sec	28.9

3.3.3.4 Adaptive ARQ Bias Parameter

The AUTO-ARQ format and modes used are shown in Figure 3.6. The "BIAS" setting of AUTO-ARQ is used to control the mode switching strategy.

ROBUST bias gives the highest error correction but lowest throughput. It also requires a long integration time in good conditions before the effective data rate is increased. ROBUST is useful in situations where conditions must be maintained on an unstable path, regardless of data throughput. This mode is most useful when fixed frequency operation below 7 MHz is the only choice (high multi-path condition). ROBUST bias uses 60% Reed-Solomon encoder efficiency. While a 255 byte block will send only 150 bytes of data, a total of 50 byte errors of that block (1/3 the number sent) may be corrected without repeat transmission.

Conversely, **FAST** bias uses minimum in-block error correction and will quickly shift to high rate modes. This mode maximizes data throughput and will be most useful on stable paths at frequencies that are near the MUF (Maximum Usable Frequency). FAST bias uses 90% coder efficiency, sending 226 data bytes per block and may correct up to 12 byte errors in each block.

NORMAL bias provides a good operational balance between error correction, throughput, and rate change responsiveness. NORMAL mode is recommended for most uses of CLOVER-II, especially when CLOVER is used in a frequency scanning HF BBS station. NORMAL mode uses 75% coder efficiency, sending 188 data bytes per block and may correct 31 byte errors in each block. FEC modes use the equivalent of "NORMAL" bias.

3.3.3.5 ARQ Connection

CLOVER has two connect modes - NORMAL and ROBUST. NORMAL connect mode is specifically designed to link two ARQ stations within 1.5 seconds. This is compatible with BBS stations that use frequency scanning receivers. ROBUST connect mode will link two ARQ stations in approximately 5 seconds and under weaker signal conditions than when NORMAL is used. ROBUST mode is most useful in fixed-frequency communications systems. Once linked, CLOVER shifts to adaptive control which is the same regardless of the connect mode chosen.

A ROBUST connection proceeds as follows:

MASTER:	Send Connect Request CCB (contains HISCALL)
SLAVE:	Send "Here Is" CCB (Acknowledges with HISCALL)
MASTER:	Send "I Am" CCB (sends MYCALL)
SLAVE:	Send Signal Reports CCB (of MASTER's signal)
MASTER:	Send Signal Reports CCB (of SLAVE's signal)

Note:

MASTER =	Station that initiated ARQ link request
SLAVE =	Station that answered ARQ link request

A NORMAL connection differs only in that a short "ping" exchange of the SLAVE's call sign is sent:

MASTER:	Send HISCALL in short "ping"
SLAVE:	Echo-back 1's complement of call sign
	Continue as for ROBUST link